AFRL-RX-WP-TP-2012-0215

REVERSE PRESSURE CAPABLE FINGER SEAL (PREPRINT)

Nathan Gibson and Joe Yanof

Honeywell International, Inc.

JANUARY 2012

AIR FORCE RESEARCH LABORATORY
MATERIALS AND MANUFACTURING DIRECTORATE
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7750
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
January 2012	Technical Paper Preprint	01 January 2012 – 01 January 2012

4. TITLE AND SUBTITLE
REVERSE PRESSURE CAPABLE FINGER SEAL (PREPRINT)

5a. CONTRACT NUMBER
FA8650-09-D-2925-0003

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
63930F

6. AUTHOR(S)
Nathan Gibson and Joe Yanof

5d. PROJECT NUMBER
ES10

5e. TASK NUMBER
00

5f. WORK UNIT NUMBER
LM1191R3

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Honeywell International, Inc.
111 South 34th Street
Phoenix, AZ 85034

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory
Materials and Manufacturing Directorate
Wright-Patterson Air Force Base, OH 45433-7750
Air Force Materiel Command
United States Air Force

10. SPONSORING/MONITORING AGENCY ACRONYM(S)
AFRL/RXLM

11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S)
AFRL-RX-WP-TP-2012-0215

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES
PAO Case Number: 88ABW 2011- 6102; Clearance Date: 18 Nov 2011. Document contains color.

14. ABSTRACT
Current pressure balanced finger seals are designed to be operated with the axial pressure difference across the seal acting in one direction. This limits their application and prevents finger seals from being used in locations where the axial pressure differential may reverse. Currently, the typical solution for locations requiring reverse capable sealing are labyrinth seals which can exhibit significantly higher leakage than finger seals as well as more degradation due to rubbing against the seal land. In this paper we discuss the application of two separate stacks of finger seal laminates oriented in axially opposed directions thereby providing sealing in both directions.

15. SUBJECT TERMS
air-to-air seals, finger seals, gas turbine engines

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT:	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON (Monitor)
a. REPORT	b. ABSTRACT	c. THIS PAGE			Rollie Dutton
Unclassified	Unclassified	Unclassified	SAR	10	19b. TELEPHONE NUMBER *(Include Area Code)* N/A

Reverse Pressure Capable Finger Seal

Nathan Gibson and Joe Yanof

Honeywell International, Phoenix, Arizona, 85034

Finger seals are a contacting air-to-air seal technology which allows for low leakage in high speed and high temperature operating conditions. Each finger seal consists of a number of multiple thin metal laminates, each with a multitude of flexible projections that are referred to as "fingers". A section of a laminate is shown in Figure 1. Note the thin slots between each finger.

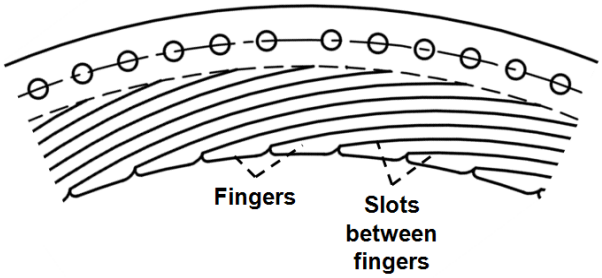

Figure 1. Finger Seal Laminate. *Each laminate contains multiple flexible fingers, separated by narrow slots. A finger seal contains two or more of these laminates, each oriented so its fingers cover the slots of the neighboring laminates.*

To form a functional seal multiple laminates are formed into a stack, with each laminate oriented so that the slots between its fingers cover the slots of the neighboring laminates. For protection and support of the laminates a forward and aft cover plate are placed on each side of the finger seal stack. A high pressure exists on one side of the seal, providing a driving force to push the air from one side of the seal to the other. Each finger of the seal remains in light contact with the rotating shaft, limiting leakage that can pass between the seal and shaft. The pressure acting on the face of the upstream laminate can cause axial loading of the fingers against the downstream plate. In some seals this axial loading is high enough to result in a high amount of friction between the downstream laminate and aft plate, as well as between the laminates themselves. This friction restricts the free motion of the fingers, preventing them from remaining in contact with the shaft and harming the seal's performance.

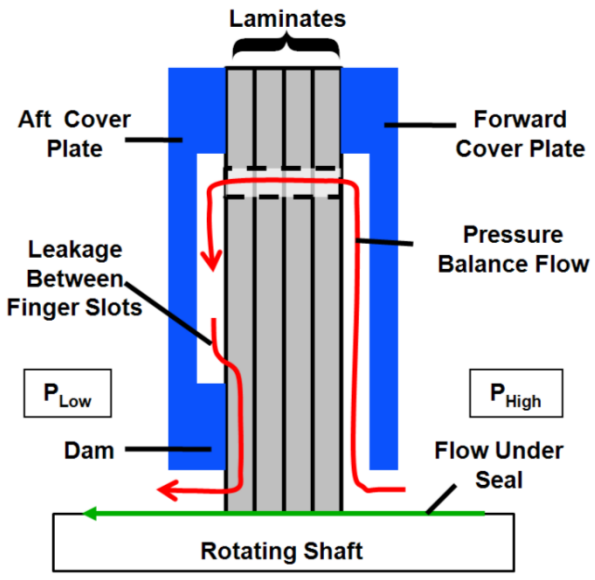

Figure 2. Typical Finger Seal Cross-Section. *This four laminate seal includes a pressure balance circuit. A small amount of air from the pressure balance circuit leaks down between the fingers, past the dam, and to the low pressure side.*

To reduce this pressure-induced friction a design has been created which includes a pressure balance circuit[1,2]. A schematic of a pressure balanced finger seal can be seen in Figure 2. As pressure is

applied to the finger seal the laminates are pressed back into the dam near the inner diameter of the aft (downstream) plate. This creates a sealed cavity between the aft plate and downstream most laminate, where air from the high pressure side can be routed, which reduces the axial loading that acts on the laminate stack.

While the inclusion of this pressure balance circuit has improved the finger seal, it has caused the seal to be functional in only a single direction as shown in Figure 3. During pressure loading in the design direction, shown in Figure 3 (a), the laminates of the finger seal are pressed into the dam by the pressure induced axial load, sealing the pressure balance cavity, except for a small flow that leaks down between the finger slots. The overall leakage of the seal is low, and the majority of air passing through the seal occurs between the shaft and laminates. For reverse pressure loading, as shown in Figure 3 (b), the pressure induced axial load pushes the laminates away from the dam on the aft plate, opening an area for leakage. This allows a large amount of leakage to flow into the pressure balance cavity, through the pressure balance circuit and to the low pressure side. The overall leakage for a reverse pressured seal will be high, with the majority of leakage passing through the pressure balance circuit. To prevent this high leakage when pressure is reversed the pressure balanced finger seal design can only be used in applications where the pressure will never reverse.

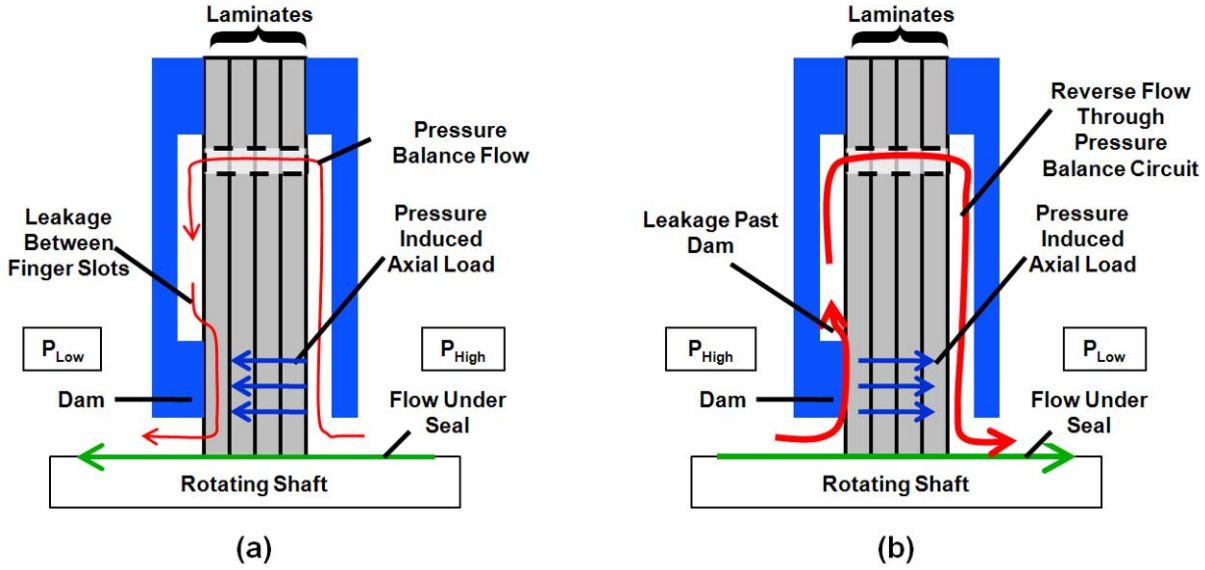

Figure 3. Flow Through Finger Seal in Intended and Reversed Direction. *(a) The finger seal has the pressure applied in the intended direction. Axial loading from pressure pushes the laminates into the dam, limiting leakage from the pressure balance cavity to the low pressure side. (b) The finger seal is loaded in the reverse direction. This pushes the laminates away from the dam, opening a leak path from the high pressure side into the pressure balance cavity. High pressure air in the pressure balance cavity flows in the reverse direction through the pressure balance circuit into the low pressure side of the seal.*

To extend the benefits of finger seals to applications that may have reversing pressures a new design is required that prevents air from traveling directly from the low side to the high side by passing through the pressure balance circuit. This can be accomplished by designing a seal that includes two

separate stacks of laminates, oriented so that air passing between the two cavities on either side of the seal must pass through both sets of laminates. A cavity exists between the two sets of laminates and a plate may be installed between them. This intermediate plate between each stack of laminates is optional and omitting it does not change the overall function of the seal. Cover plates are installed at either end of this seal which each contain a pressure balance cavity and dam. This reverse capable finger seal arrangement is shown in Figure 4.

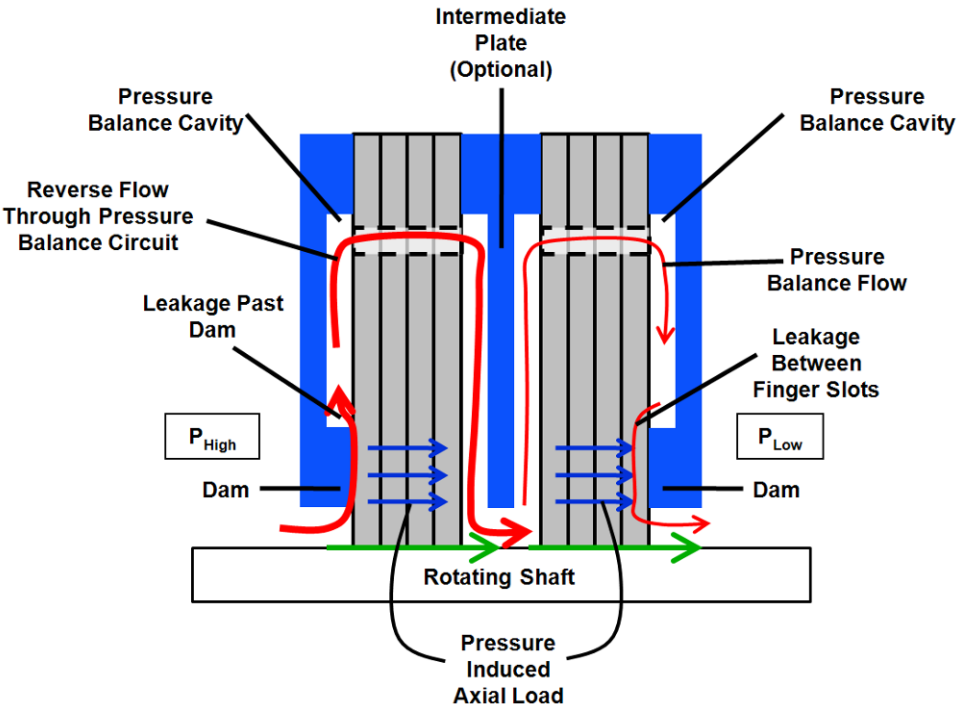

Figure 4. Reverse Pressure Capable Finger Seal. *Two stacks of finger seals are installed in line with each other. At either end, cover plates with their own pressure balance cavities and dams are installed. When a cavity on one side of the seal is pressurized higher than the other the laminates on that side will be deflected away from the dam by the pressure induced axial load, allowing air to flow through the pressure balance circuit to the cavity between the seals. This pressure then acts on the second set of laminates which is pushed into its cover plate, limiting leakage through the pressure balance circuit.*

When pressure is applied to the reverse capable finger seal design the upstream set of laminates (the set of laminates on the side of the seal facing the high pressure) is pushed away from the dam on its cover plate, similar to the laminates of the seal shown in Figure 3 (b). As air leaks past the upstream laminates it flows into the pressure balance cavity, through the pressure balance circuit and into the cavity between the two sets of laminates, causing it to pressurize. Due to the rising pressure in the cavity between the sets of laminates the downstream set is axially loaded into the dam on the downstream cover plate. This causes the downstream set of laminates to function similarly to the

laminates of the seal shown in Figure 3 (a) which prevents air from leaking to the low pressure side of the seal.

The direction of pressure applied to the seal shown in Figure 4 can be reversed and the two sets of laminates will also reverse roles, with the set formerly acting as the upstream laminates become the downstream and vice versa. In this reversed pressure case the one set again will be pushed away from its dam, allowing leakage to occur while the other set will be pressed into the dam on its cover plate. This allows the seal to function equally well in either direction

The following aspects of this design have been considered and could be incorporated into the design of the reverse pressure capable finger seal if needed for particular applications:

1. Different diameters for the two different sets of laminates
2. Omission of the intermediate plate between the two sets of laminates
3. Fastening all laminates and cover plates together as a single assembly
4. Incorporating the features of the cover plates into neighboring hardware
5. Use of laminates with different finger stiffnesses than other laminates of the same seal

[1]Arora, G.K., and Glick, D.I., Allied Signal (Now Honeywell International), Morris Township, NJ, U.S. Patent "Pressure Balanced Finger Seals," U.S. Patent No. 6,196,550, Mar. 6, 2001

[2]Arora, G.K., Proctor, M.P., Steinetz, B.M., and Delgado, I.R., "Pressure Balanced, Low Hysteresis, Finger Seal Test Results," AIAA-99-2686, 1999

Acknowledgement of Sponsorship: The project or effort depicted is sponsored by the Air Force Research Laboratory (AFRL) under contract FA8650-09-D-2925 Task Order 0003.